Armed Forces College of Medicine

AFCM

Coronary, cerebral and cutaneous circulations physiology

Dr Manal Said

Physiology Assistant Professor

INTENDED LEARNING OBJECTIVES (ILO)

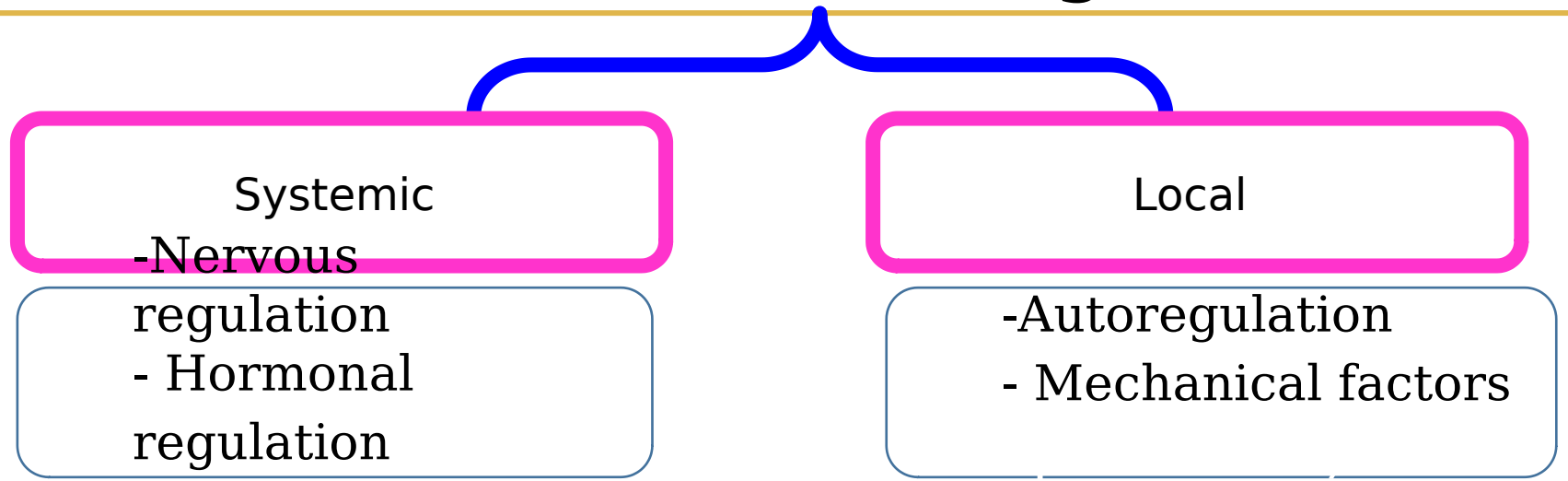
By the end of this lecture the student will be able to:

- Describe the coronary blood flow and its phasic changes during the cardiac cycle.
- States the relative importance of local metabolic and neural control of coronary, cerebral and skin blood flow
- Describe the regulation of the coronary, cerebral and skin blood flow.
- Apply the information studied in this section to solve a clinical problem or explain clinical case.

Lecture Plan

- Principles of blood flow regulation (5 min)
- Regulation of coronary circulation (15 min)
- Regulation of cerebral circulation (10 min)
- Blood brain barrier physiology (5 min)
- CSF physiology (5 min)
- Regulation of cutaneous circulation (10 min)
- Summary and quiz (5 min)

Blood flow regulation



Coronary and cerebral circulations	Cutaneous circulation
Vital organs regulated mainly by autoregulation	Non- vital organs, no autoregulation
sympathetic vasomotor tone is minimal.	sympathetic vasomotor tone is maximal.

Coronary circulation

I- characters of coronary blood flow

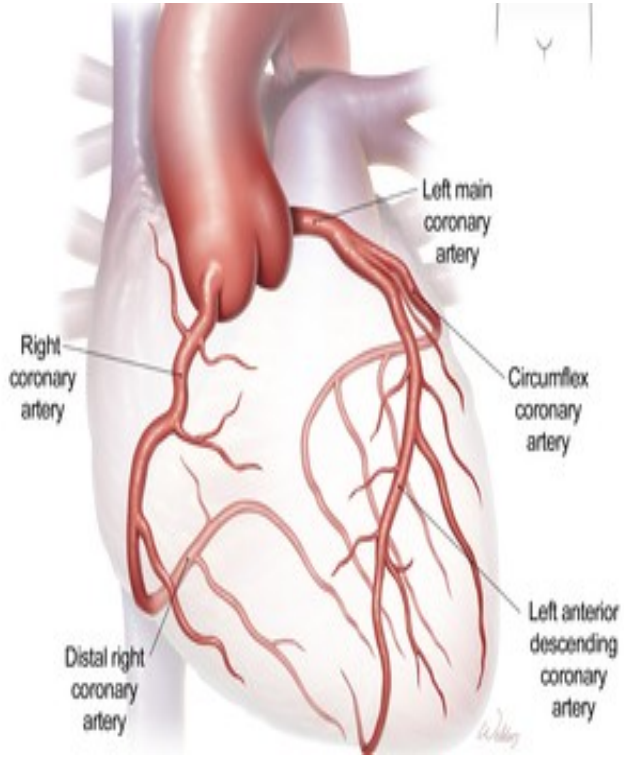
1-<u>During rest</u>: 4% of cardiac output= 250 ml/min.

2- <u>High oxygen extraction ratio</u> is70%, low venous oxygen reserve

So, during exercise: increased coronary blood flow is the only way to increase oxygen supply to heart

3- High capillary density one capillary/one muscle fiber

4- Coronary vessels are functionally end arteries with no sufficient anastomosis. Acute coronary obstruction causes myocardial infarction because cardiac muscle is an aerobic



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II- Coronary blood flow regulation

- **1- Coronary autoregulation: mainly metabolic (chemical) mechanism, myogenic**
- **2- Mechanical factors:**
  - **A- Phasic changes during the cardiac cycle**
  - **B-Aortic pressure**
  - **C-Regional distribution of blood flow**
  - **D- Heart rate**
- **3- Neural factors**
- **4- Humoral factors**

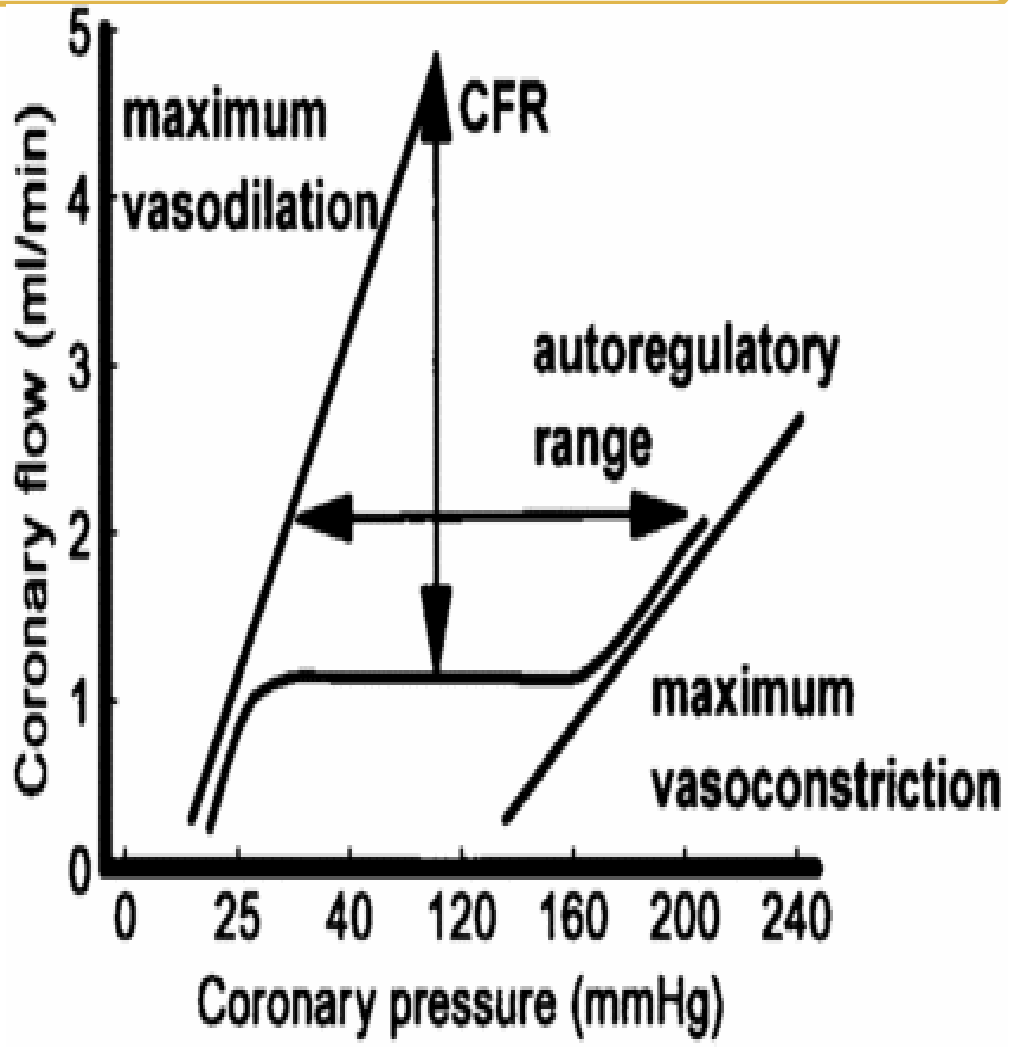
1- Coronary autoregulation

- **Definition:**

❖Intrinsic capacity to maintain constant blood flow in spite of the changes in coronary perfusion by altering the vascular diameter

❖Most prominent over the pressure range (about 60 to 140 mm Hg).

❖Myogenic and metabolic theory



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1- Coronary autoregulation

- **mechanism:**

❖ Myogenic and metabolic theory

❖ ***Local metabolism is the primary controller of coronary flow.***

- **Decrease coronary perfusion or increase cardiac activity** will lead to:

❑ ***Decrease oxygen (oxygen demand)***

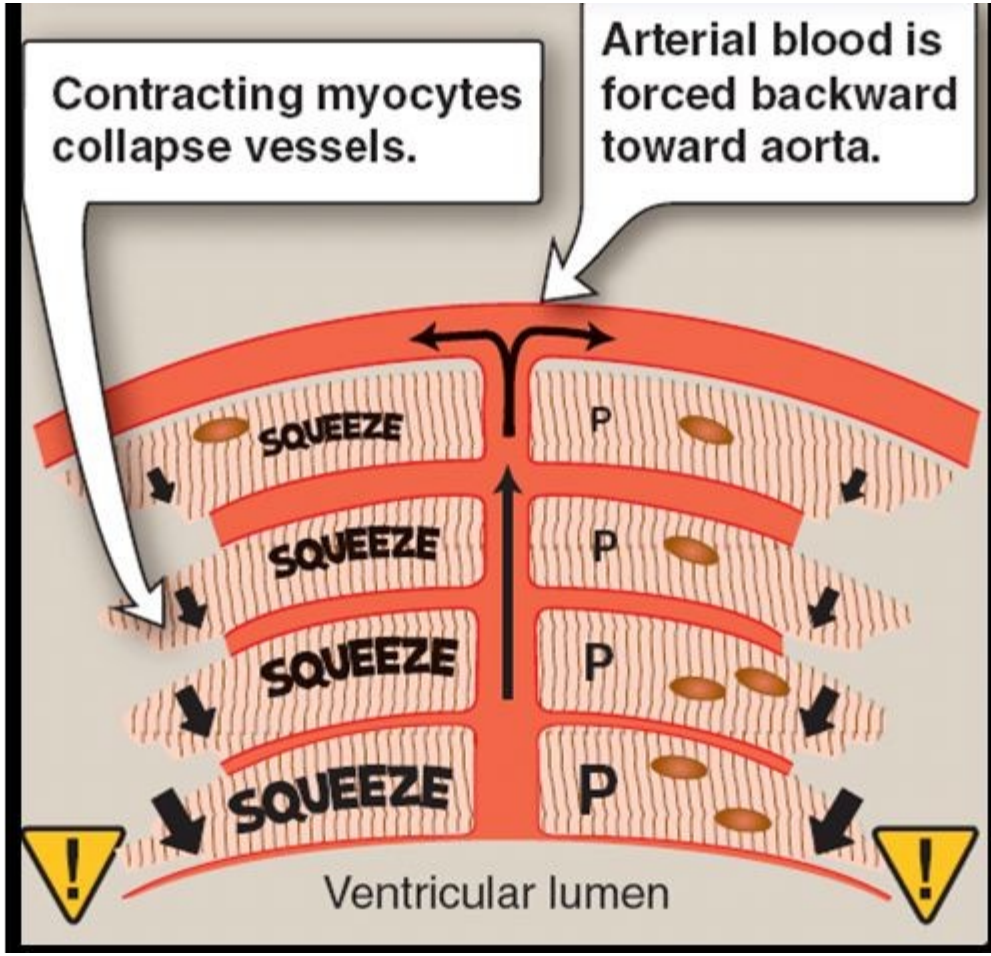
❑ ***Increased: Co2, K+ , Adenosine, H+***

❑ **Adenosine** is a potent vasodilator and it increases the blood flow to cardiac muscle

- **Response:** Dilatation of coronary vessels and increased blood flow to cardiac muscle

2- Mechanical factors:
A- Phasic changes during the cardiac cycle

- **During systole**
- Intramyocardial pressure increases and compresses the coronary vessels, coronary blood flow decreases (briefly reversed)
- **During diastole**
- Intramyocardial pressure decreases, coronary blood flow increases



Lippincott Illustrated Reviews: Physiolo

2- Mechanical factors:

A- Phasic changes during the cardiac cycle

Left coronary artery maximal flow:

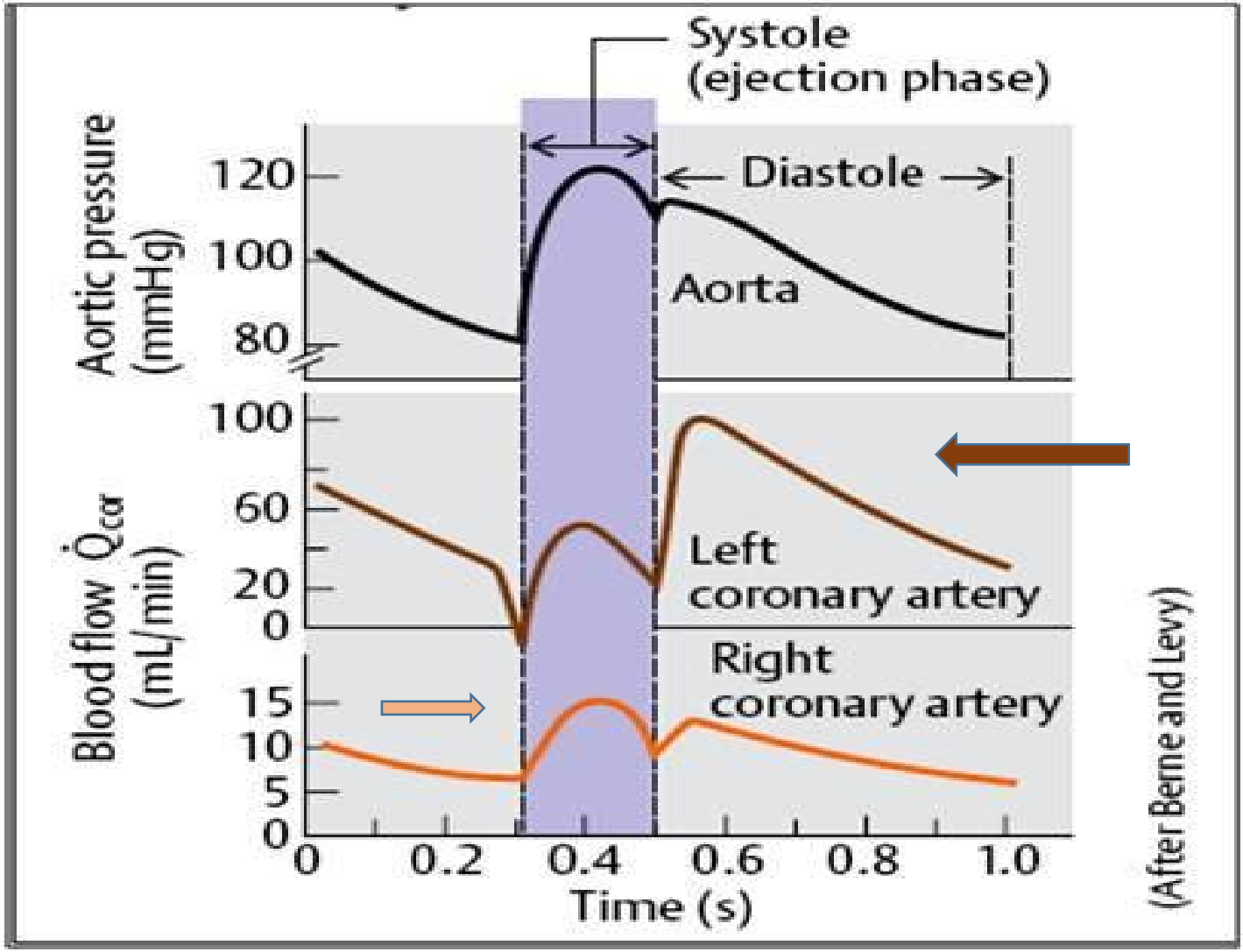
isovolumetric relaxation phase

Aortic pressure Higher than left ventricle pressure + Reactive hyperemia

Right coronary artery maximal flow

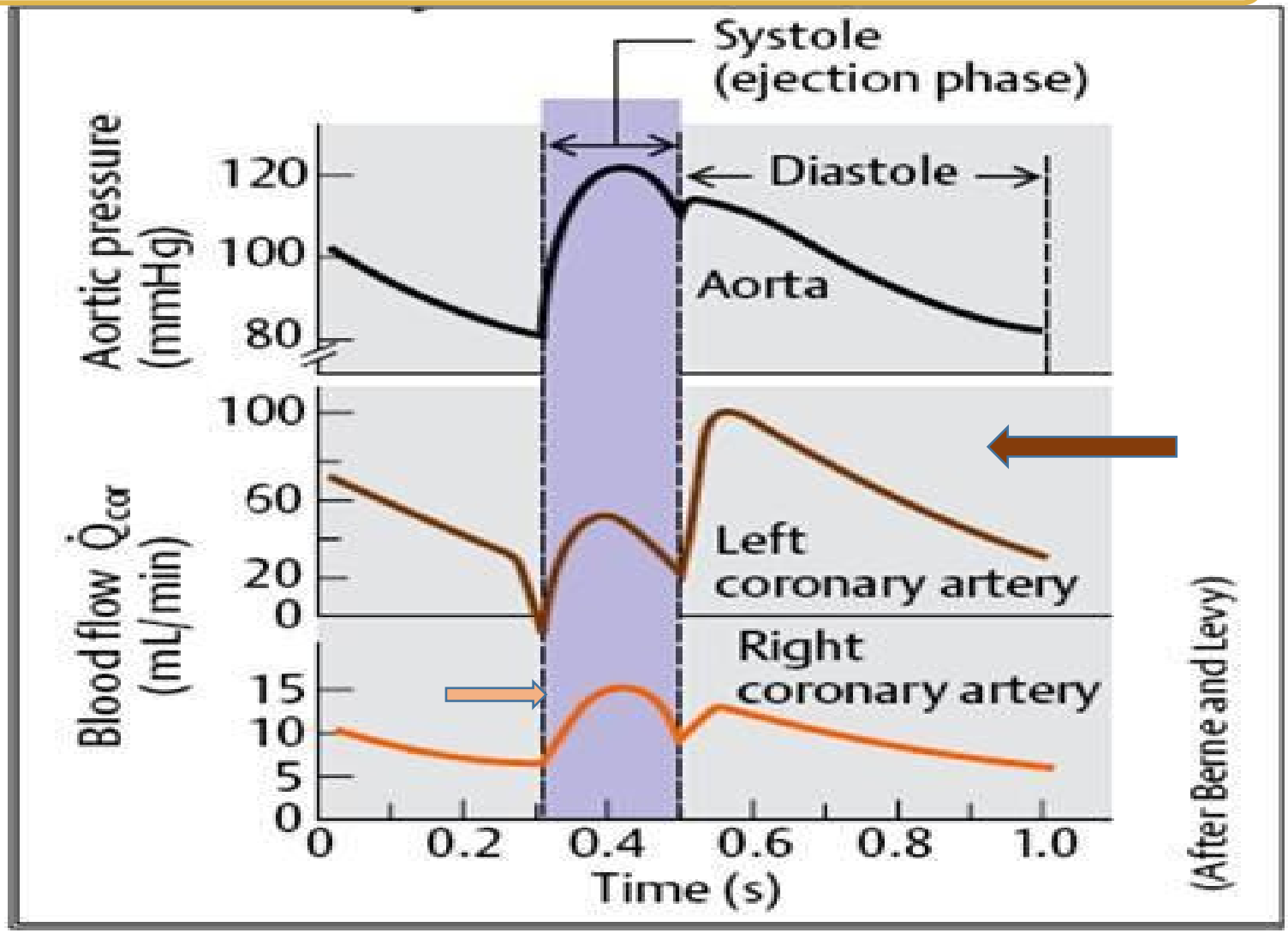
rapid ejection phase

Aortic pressure

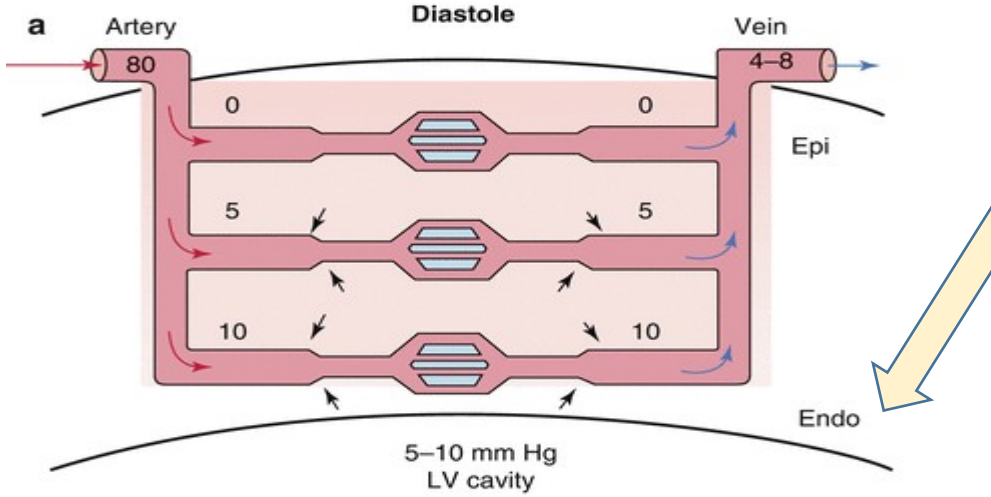


Mechanical factors: -2
:B- Aortic pressure

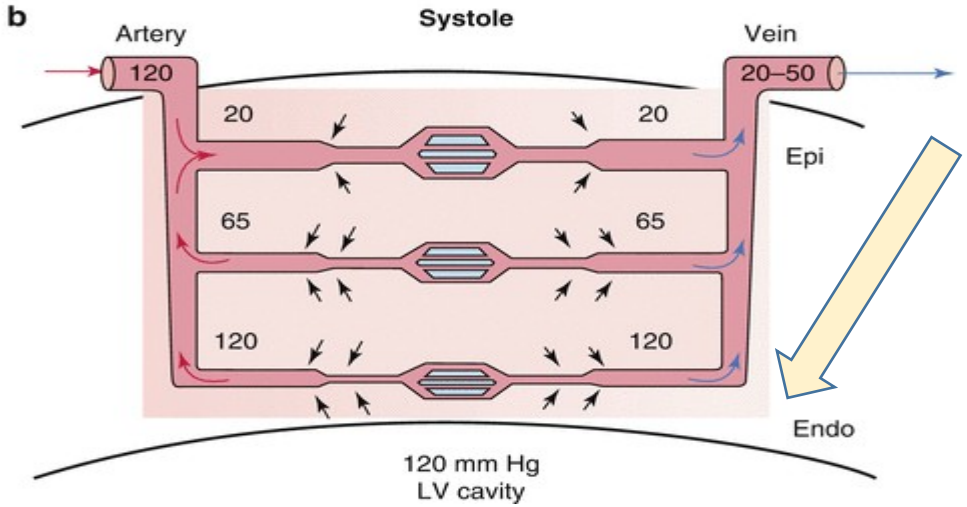
- Coronary blood flow is directly proportionate to the diastolic aortic pressure
- Coronary flow decreases in shock, aortic incompetence



2- Mechanical factors:



- **C-Regional distribution of blood flow:**
- **Subendocardial layer :**
- **Blood flow stops** during isovolumetric contraction phase due to high intramyocardial pressure.
- More susceptible to ischemia



- **D- Heart rate:**
- left ventricular coronary flow is reduced during tachycardia
- Because diastole is shorter when the heart rate is high

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3- Neural factors:

- **Direct action**; sympathetic decreases coronary blood flow acting on alpha receptors
- **Indirect action:**
- Increasing metabolic activity with oxygen lack leads to vasodilatation

4- Humoral factors:

Catecholamines act on beta receptors causing coronary vasodilatation

- Nitric oxide released from vascular endothelium Due to shearing forces due to increased coronary flow
- Endothelial derived relaxing factor: increased coronary flow
- Histamine: increased coronary flow

Clinical application

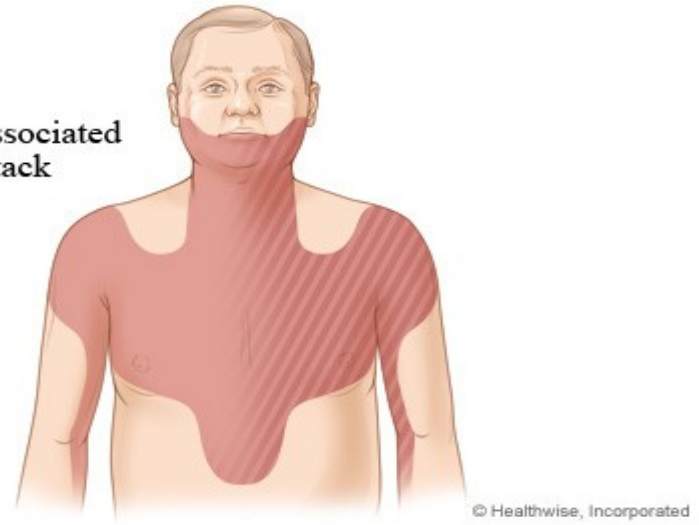
partial obstruction of the coronary artery by spasm or atherosclerosis

-Angina pectoris

complete lack of blood supply due to total occlusion of a coronary vessel

-Myocardial infarction

- **<u>Main symptom</u>**
- Pericordial, substernal pain, often referred to left arm, left shoulder radiate to the neck



Angina pectoris

- Recurrent short lived attacks of inadequate coronary blood flow during exertion or emotional tension associated with pain

Treated by :

A) Nitrites:

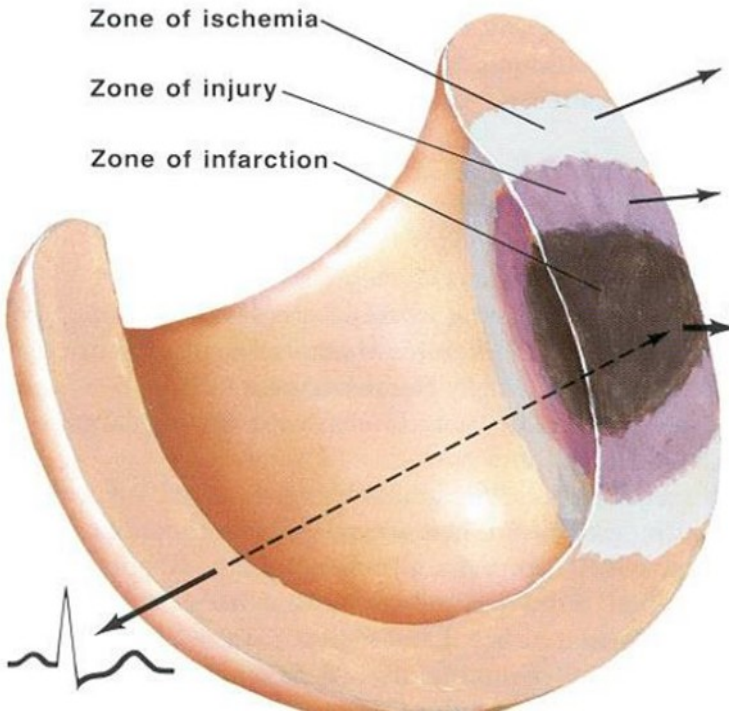
They decrease preload and afterload to meet oxygen requirements

B) Slight exercise:

Hypoxia and adenosine accumulation the most important coronary dilator and stimulate angiogenesis

Myocardial infarction

- Necrosis of the cardiac muscle fibers followed by fibrosis
- **ECG changes;**
- Raised ST segment: current of injury
- Inverted T wave: ischemia
- Deep Q wave: electric window



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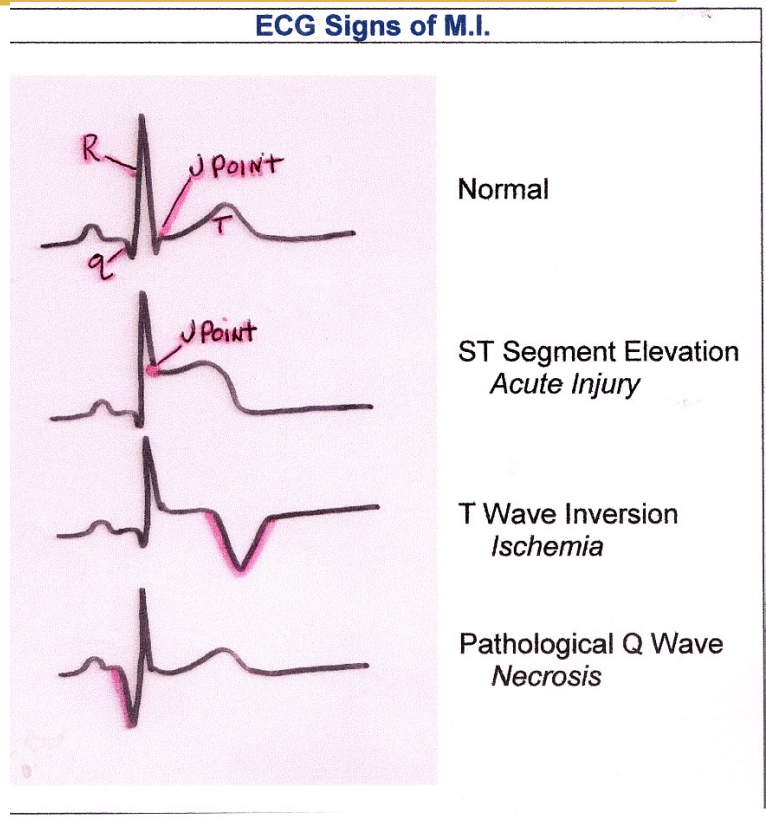

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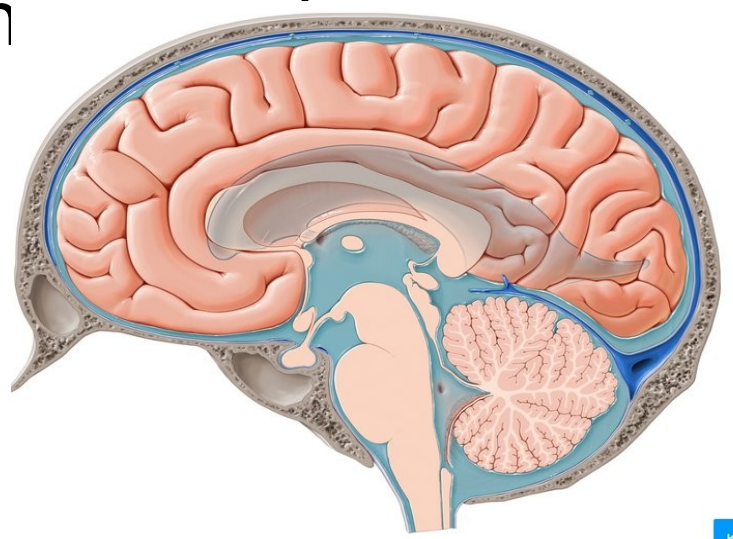
Cerebral circulation

1- characters of cerebral circulation

1. Brain receives blood from the **basilar artery** and **internal carotid artery that form circle of Willis**
2. Each internal carotid supply ipsilateral hemisphere no crossing over
3. Cerebral arteries are end arteries
4. Brain has an aerobic metabolism and uses glucose as main energy source
5. Brain receives 13% of cardiac output (756 ml/min)
6. Total cerebral blood flow is constant, unchanged during sleep or mental activity
7. Regional variation: Coupling between local metabolic rate and CeBF: it increases in left motor cortex while voluntary clenching of right hand
8. Cerebral capillaries form the blood brain barrier

1- characters of cerebral circulation

- 9- According to the ***"Monro-kellie doctrine***
- **Brain tissue**, **cerebrospinal fluid (CSF)** and **cerebral blood vessels** are enclosed in the rigid skull with the overall volume kept constant
- **Brain tissue** is not compressible
- The cerebral arteries are compressed by in intracranial pressure or cerebrospinal fluid

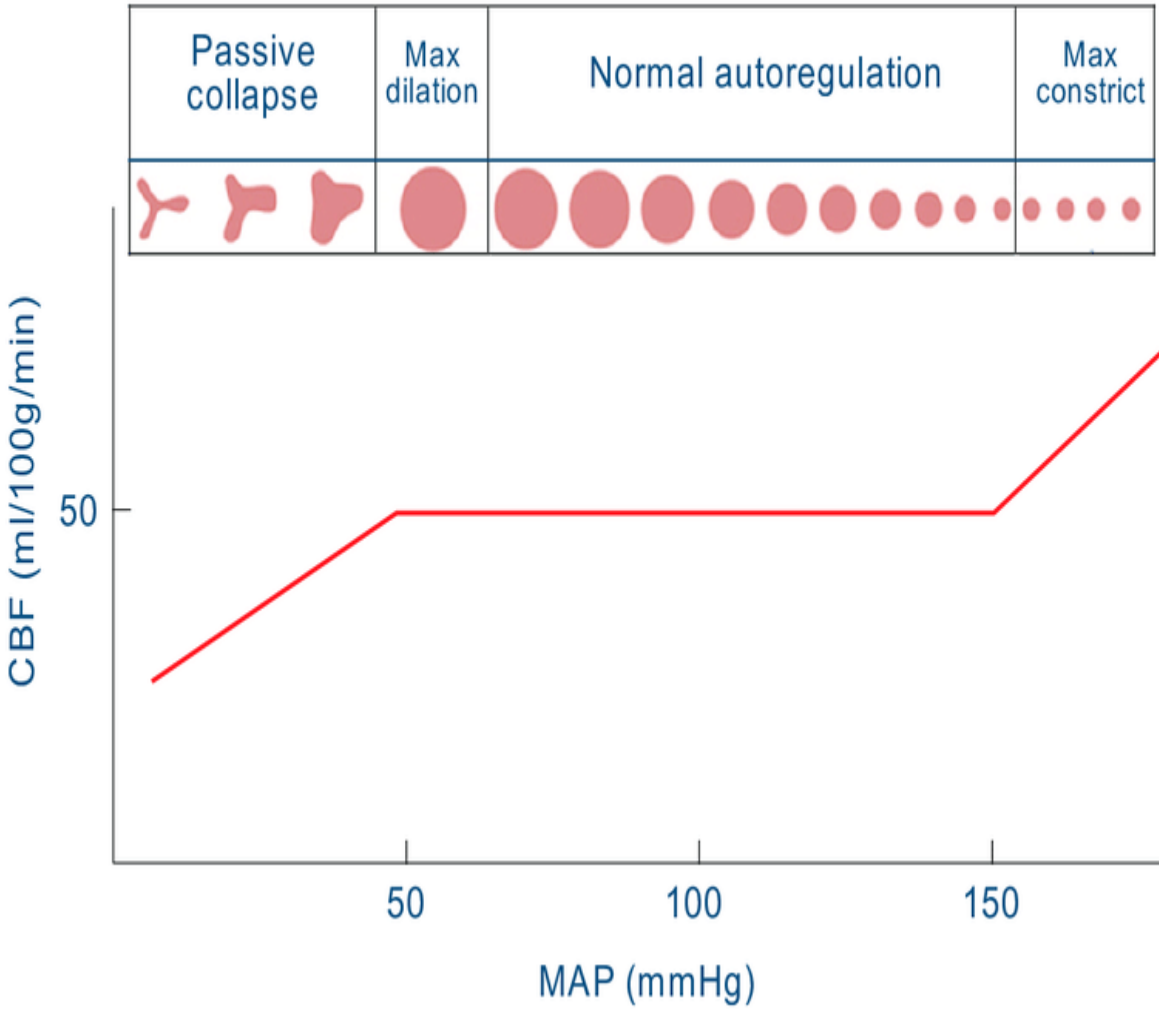


2- Regulation of cerebral blood flo

A. Cerebral autoregulation
B. Chemical factors
C. Mechanical factors
D. Neural factors

A- Cerebral autoregulation

- ***Definition***:
- Cerebral blood flow (CeBF) is kept nearly constant despite variations in perfusion pressure, range at MAP (60 – 140) mm Hg.
- **Myogenic :** vascular smooth muscles of cerebral arterioles respond to stretch by vasoconstriction
- **Metabolic:** CO2 is the main cerebral vessels dilator



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B- chemical factors

Blood gases:

1- Carbon dioxide:

- **strong vasodilator, Most important determinant of cerebral blood flow**
- The **increase in PCO2** will **increase H+ ion concentration in CSF, hydrogen is a potent dilator.**
- Hyperventilation and wash out of carbon dioxide leads to decrease in cerebral blood flow, **dizziness, loss of consciousness**

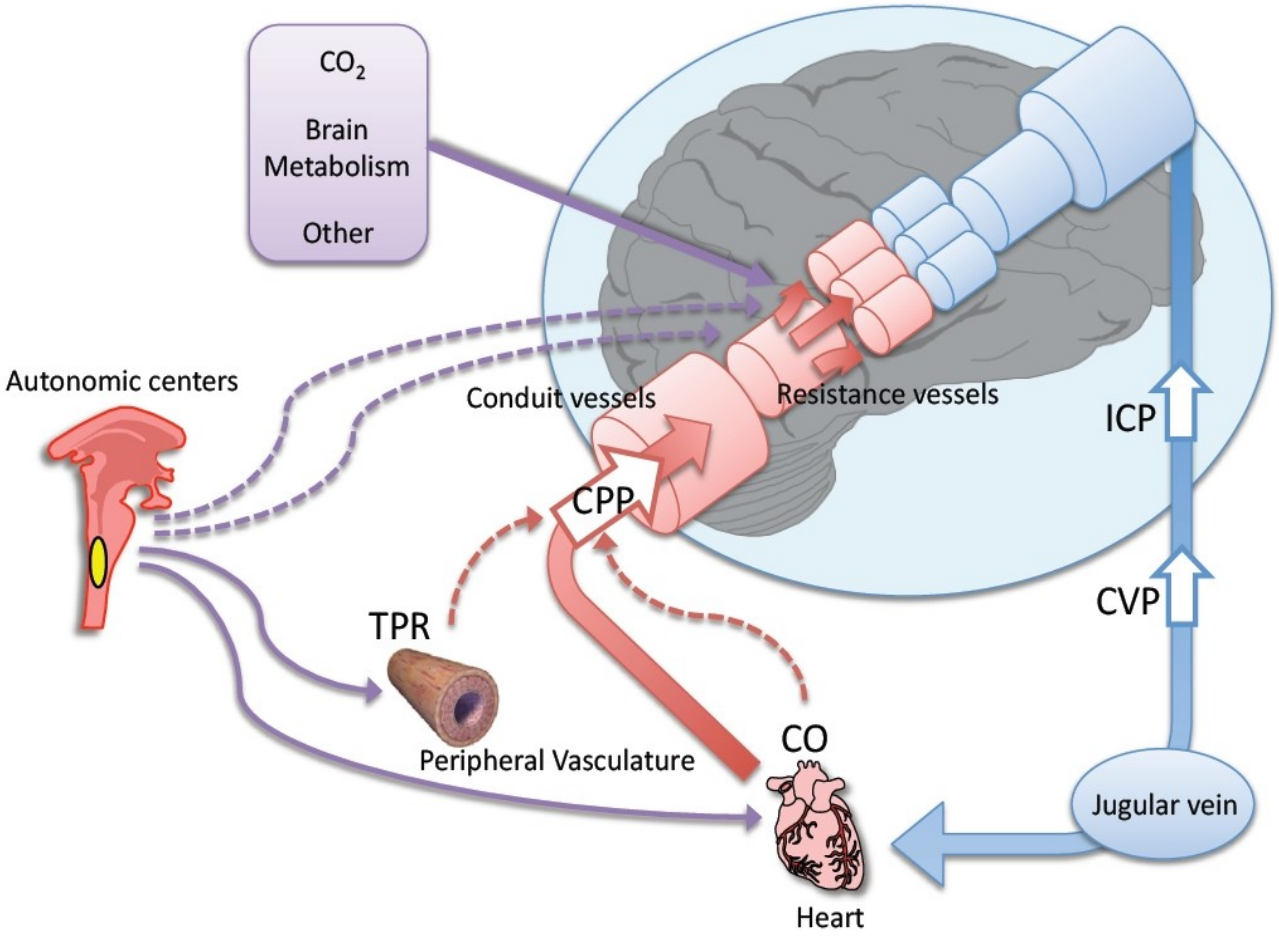
2- Oxygen:

- Hypoxia increases cerebral blood flow by dilatation
- Effect of hypoxia starts when PO2 is less than 50 mmHg

B- chemical factors

- **Metabolic products: Adjust regional CeBF to the metabolic neural activity**
  - **Hydrogen**
  - **Potassium**
  - **Adenosine: potent dilator**
- **Nitric oxide :**
  - **potent vasodilator.**
  - **Important role in regulation of basal cerebral blood flow**
- **Systemic vasoconstrictors don’t cross BBB**

C- Mechanical factors



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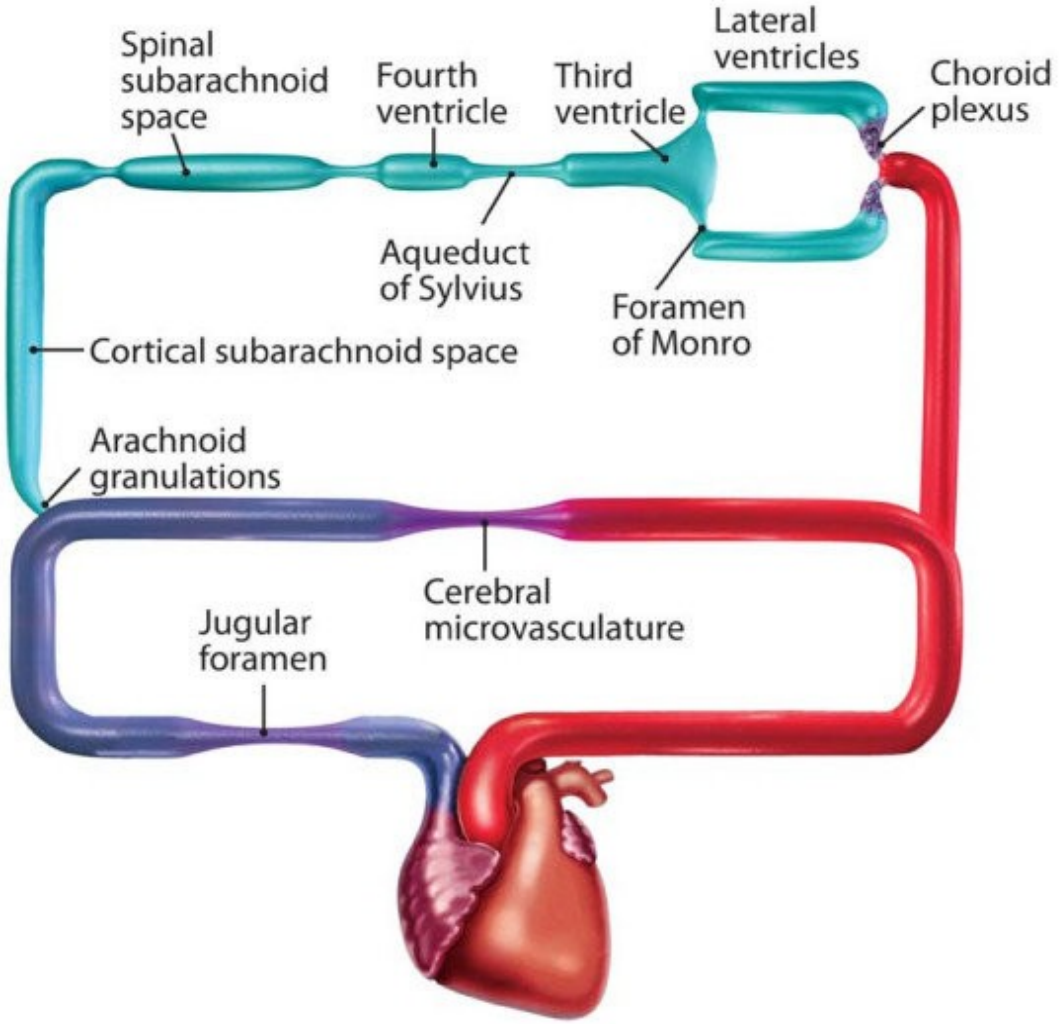

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C- Mechanical factors

- **Cerebral effective perfusion pressure=** ABP at the head level – VP in internal jugular vein (near zero)
- **Cerebral blood flow depends on the balance between cerebral perfusion pressure and intracranial pressure (ICP)**

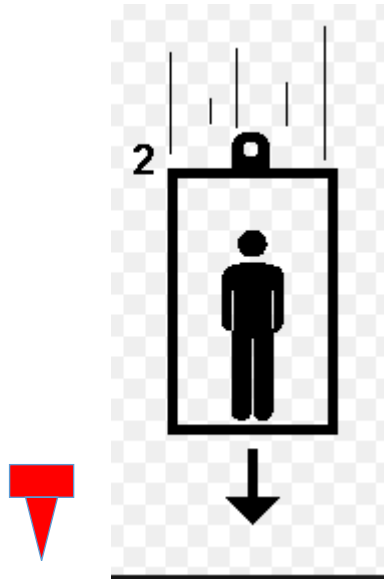
Increase CeBF	Decrease CeBF
Increase in ABP	**Increase in internal jugular venous pressure:** ➢ Decrease cerebral effective perfusion pressure ➢ Impair CSF drainage and increase CSF pressure and ICP
	Increase in intracranial pressure (ICP) normal 10-12 mmHg:

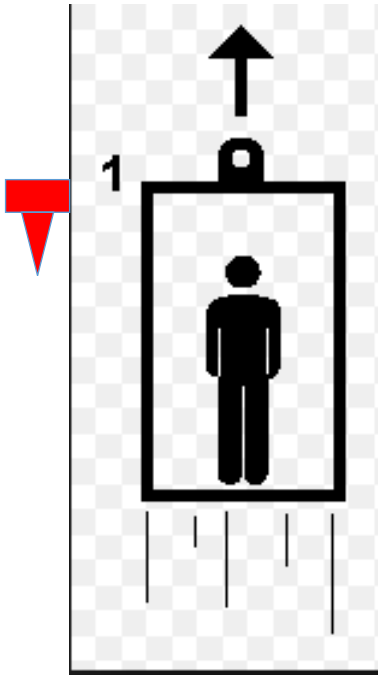
C- Mechanical factors

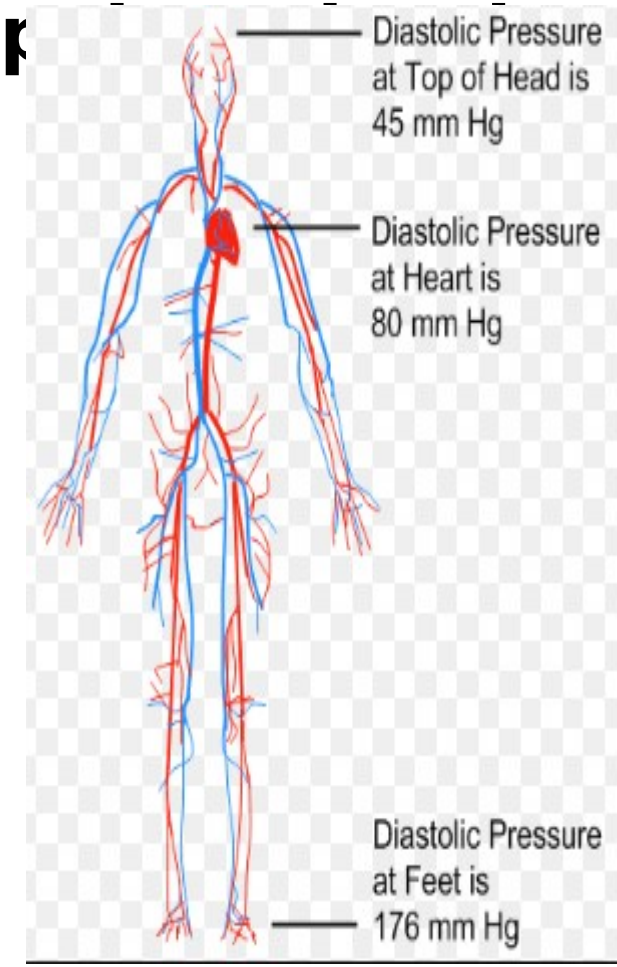
	CNS ischemic response	Cushing reflex
Stimuli	Decreased blood pressure< 50 mmHg	Increased intracranial pressure
	Cerebral arterial pressure < intracranial pressure	Intracranial pressure >Cerebral arterial pressure
	Decrease cerebral blood flow leads to s**evere oxygen lack, increased Co_2**	
Center	Direct stimulation to ischemic neurons of **Pressor area of VMC** stimulate sympathetic adrenergic fibers **(α1)**	
response	Strong vasoconstriction, hypertension and associated Bradycardia **{baroreceptor effect}**	

C- Mechanical factors: effect of gravity

- **[illegible] CSF pressure (ICP), are balanced at all p[illegible] cranium.**
- **Upright posture:**
- **Upward acceleration:**
- Blood moves down to feet
- **Downward acceleration:**
- Blood moves up to head







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D - Neural factors

- Neural control plays little role in regulation of cerebral blood flow.
- In hypertension sympathetic noradrenergic discharge produces strong vasoconstriction on large cerebral arteries.
- Aim: prevents the passive increase in blood flow and helps to protect the blood brain barrier

❖ **Note:**

- Increase **blood viscosity** increase **cerebral vascular resistance** and decrease cerebral blood flow

Brain Blood barrier

- It separates the circulation from the brain
- **Formed of:**

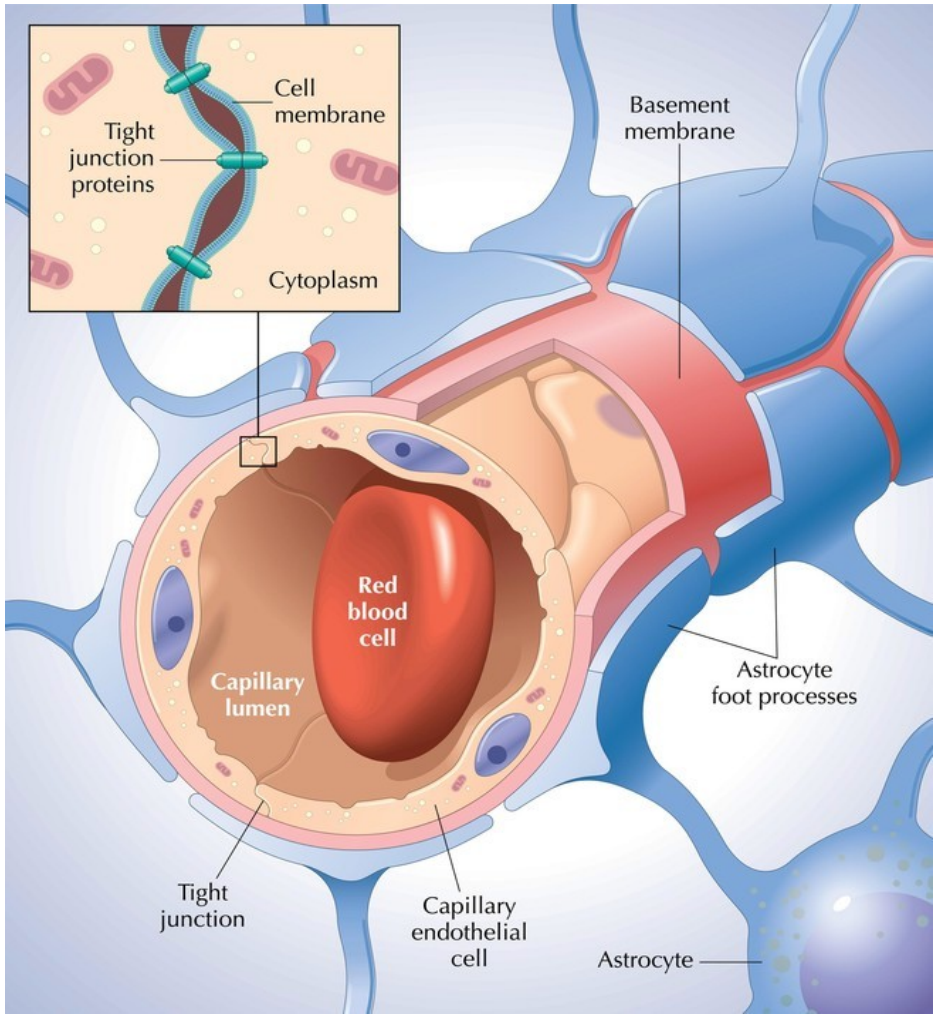
1. Tight junctions between endothelial cells
2. Prominent basement membrane
3. Pericytes: maintain tight junction stability
4. The cytoplasmic foot processes of the astrocytes that surround vessels

- **Function:**

❖ Maintain constant ionic composition, PH in neural environment

❖ Protects brain from endogenous, exogenous toxins

❖ Prevents neurotransmitter escape to the blood stream



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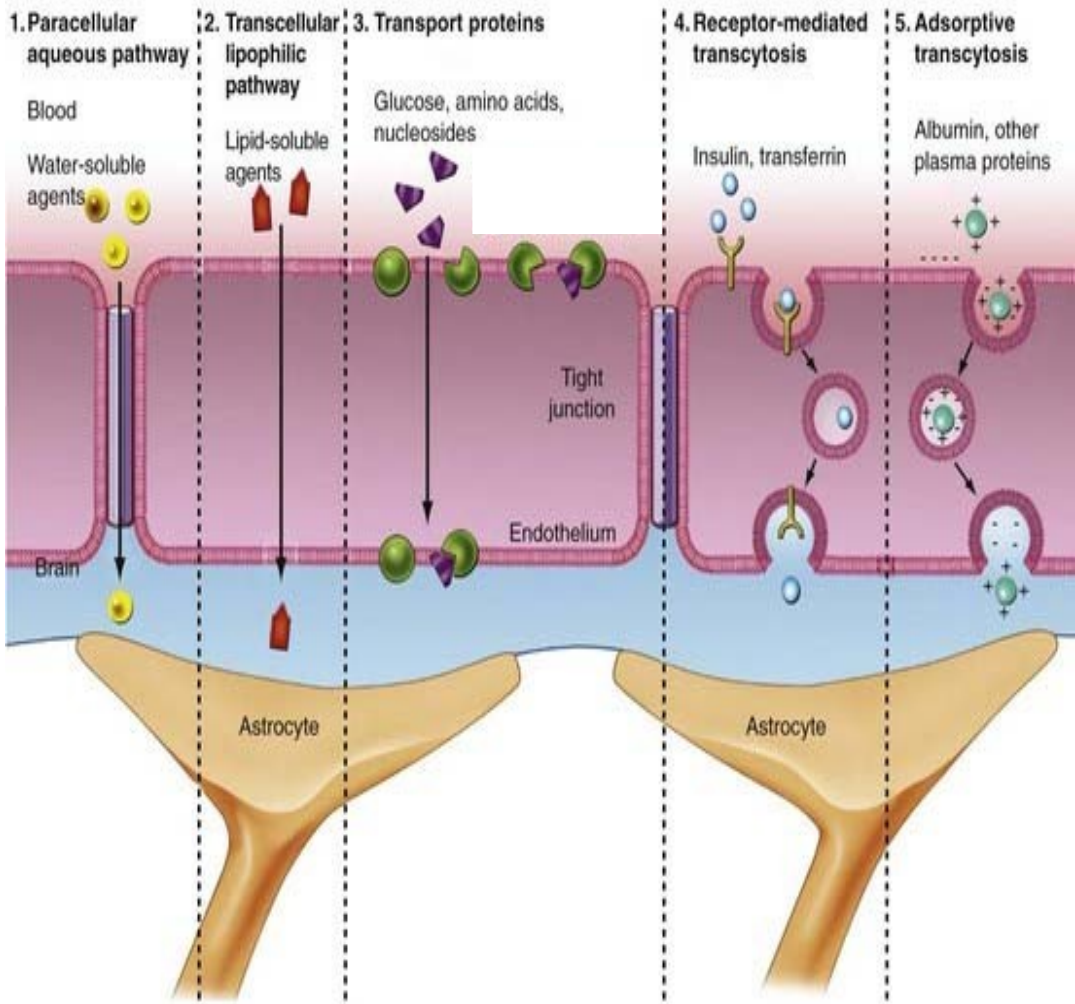
Brain Blood barrier

- **Permits** o_2, **co_2**, H_2o, lipid soluble substances as alcohol, ammonia, anesthetic drugs, steroid hormones
- **Prevents** passage of proteins, hormones and bile pigments
- Proteins transport is limited and depends on **vesicular transport**
- Glucose uptake by facilitated diffusion insulin independent (GLUT 1)



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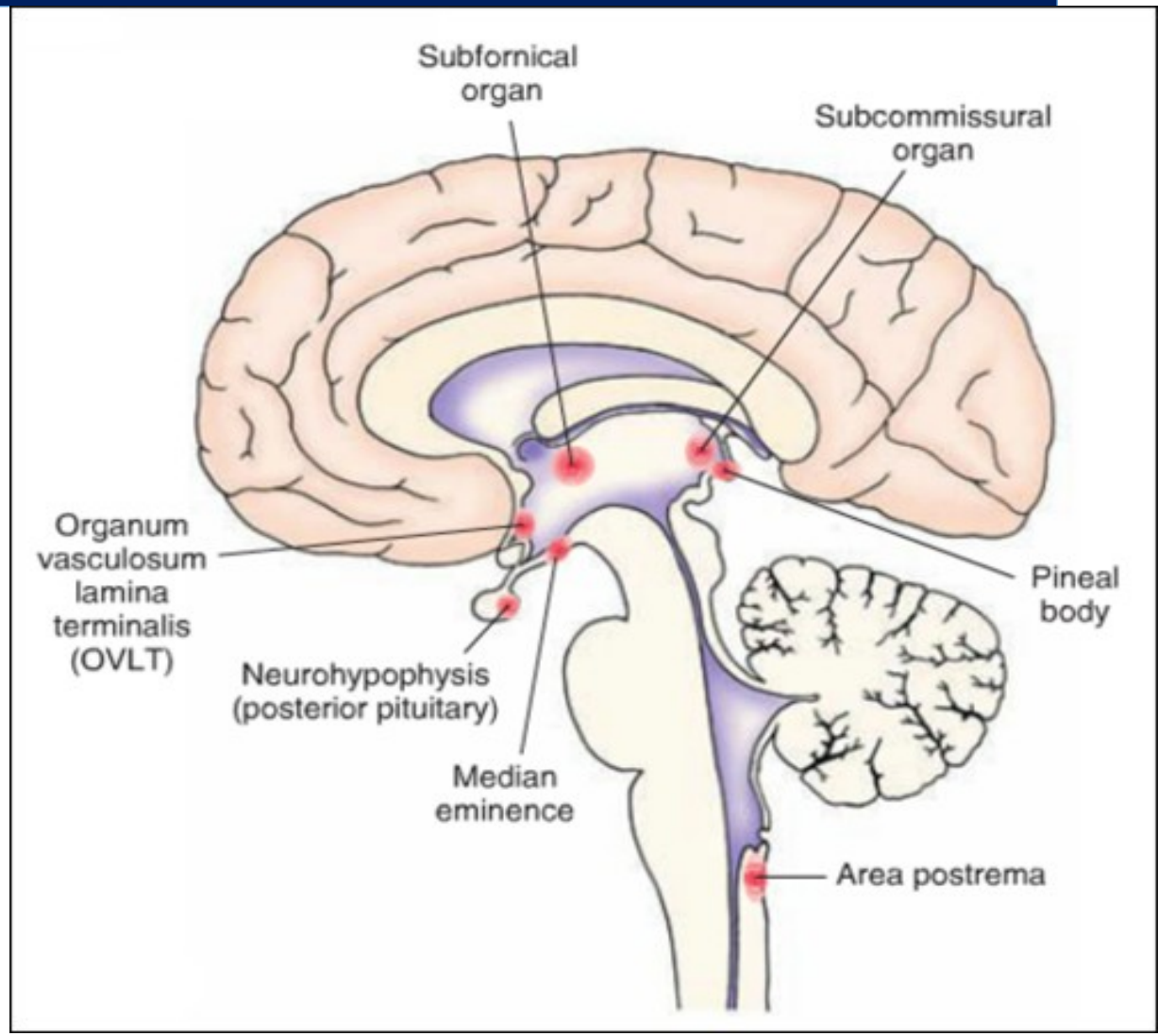
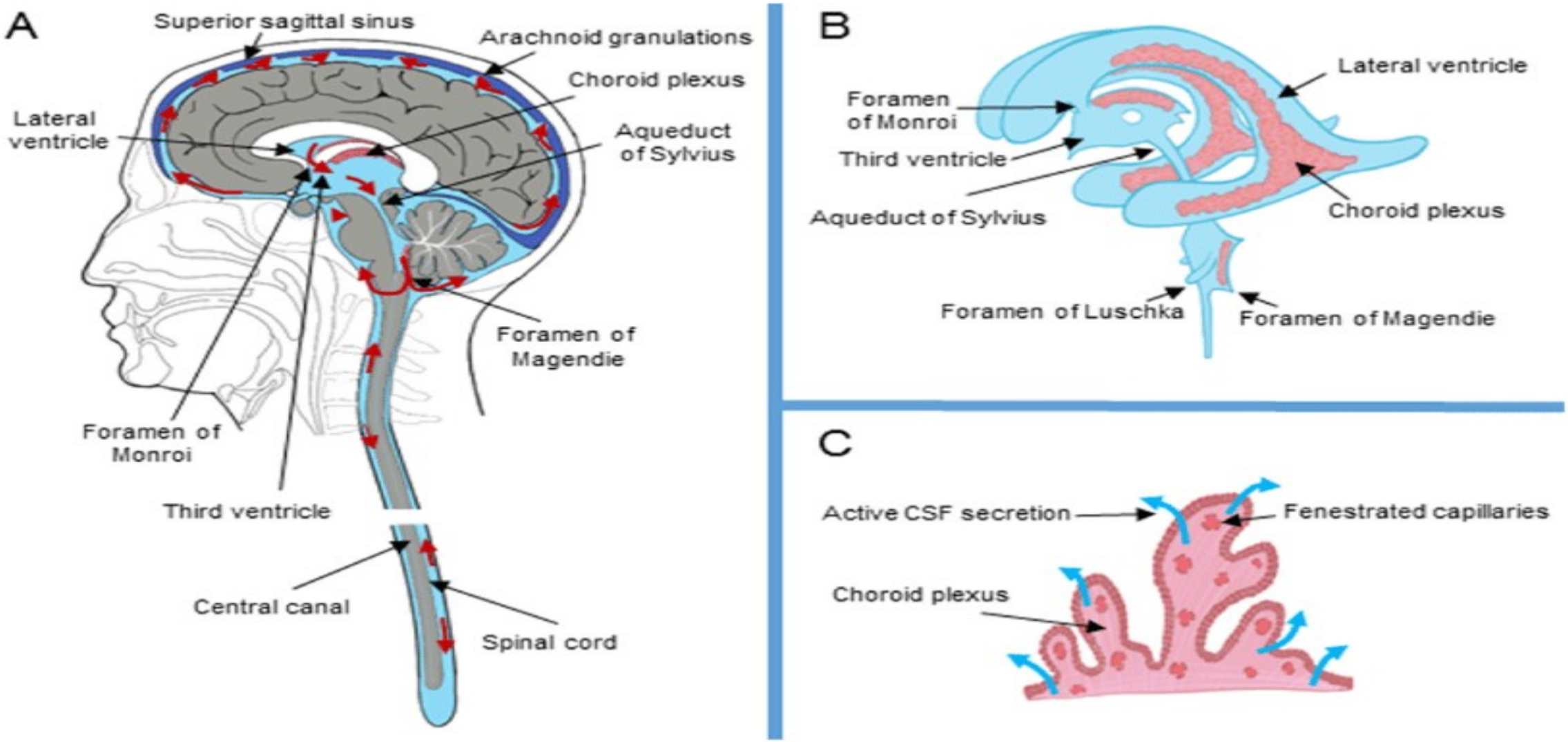
Some brain parts that lies outside BBB

- Collectively, called **<u>Circumventricular organs</u>**

Posterior pituitary	Secretes ADH, oxytocin
Area postrema contain Chemoreceptor zone	Initiates vomiting
Organum vasculosum of lamina terminalis contain osmoreceptors	control ADH secretion
Subfornical organ	Increase water intake



Cerebrospinal fluid



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Cerebrospinal fluid

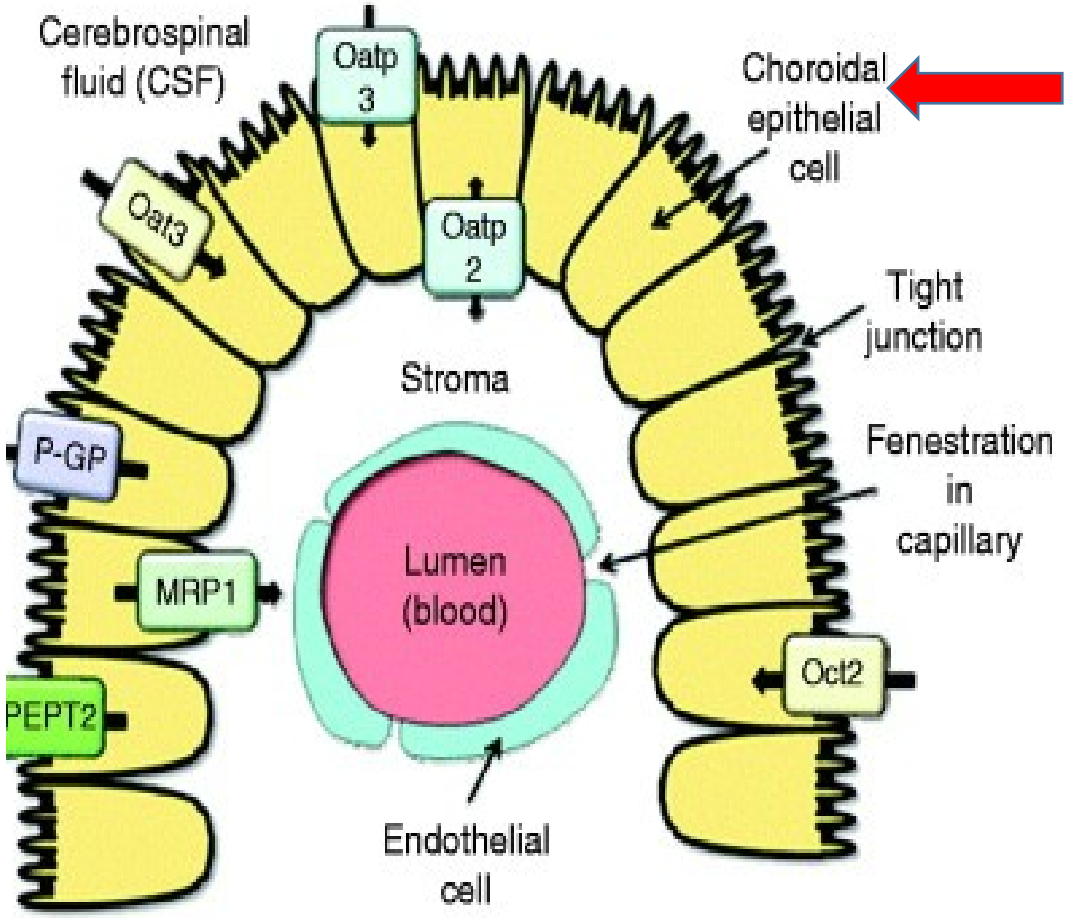
- Formed from the choroid plexus by active secretion
- Absorbed by bulk flow (depend on hydrostatic pressure) to venous sinus
- Composed of clear fluid, 150 ml, Compared to plasma it has More $Co_{2,}$ H^{+}

Less proteins, cholesterol, glucose

Functions:

Protection the brain tissue from injury when jolted or hit

rinsing the metabolic waste



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Cutaneous circulation

2- Regulation of cutaneous blood flow

A. Mainly neural:

- Richly supplied by sympathetic vasoconstrictor nor-adrenergic fibers act on alpha receptors causing vasoconstriction (tonic vasoconstriction). It is regulated by baroreceptor reflex.
- Sympathetic cholinergic dilator fibers to sweat glands to stimulate sweating with active vasodilatation

- No parasympathetic vasodilator fibers

Cutaneous vascular reactions

- **Stimuli:**
- Scratching the skin strongly with a blunt object leads to the appearance of the following 3 cutaneous reactions:

➢Red line: capillary dilatation due to histamine effect

➢Flare phase: Arteriolar dilatation {Local axon reflex}

➢Wheal: histamine-induced increase in capillary permeability

- **Tripple response**

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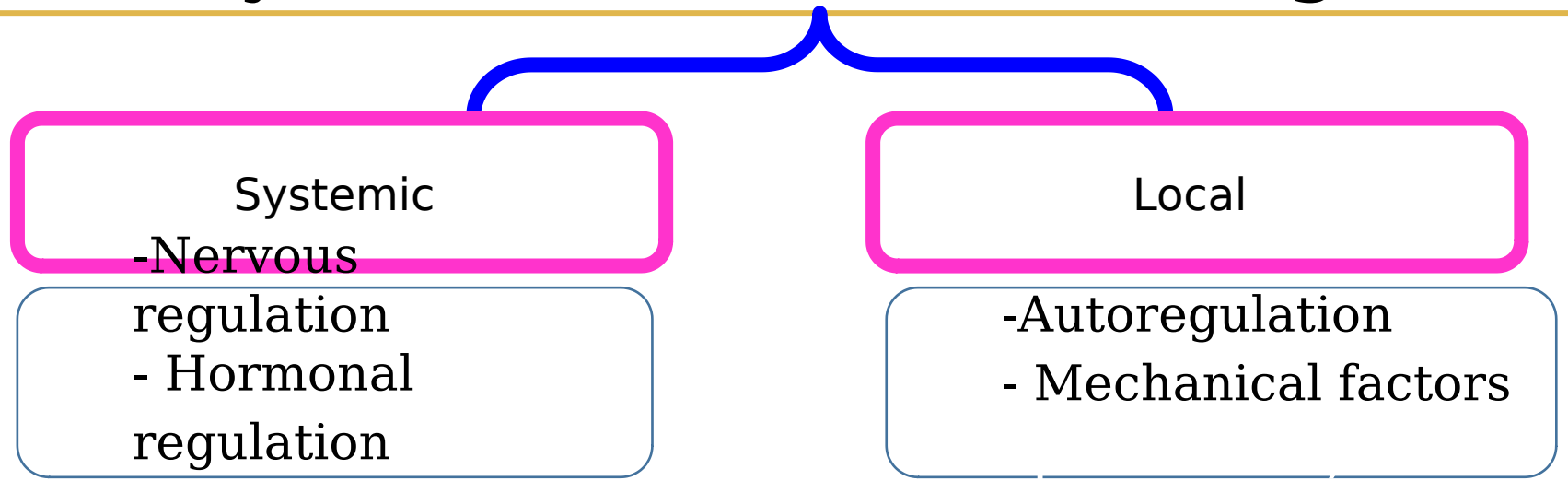
Summary: Blood flow regulation



Coronary and cerebral circulations	Cutaneous circulation
Vital organs regulated mainly by autoregulation	Non- vital organs, no autoregulation
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Lecture Quiz

- 1- which of the following circulation is affected mostly by the sympathetic vasoconstrictor nerves?
- A- Cerebral
- B- coronary
- C- Hepatic
- D- Cutaneous
- 2- Which part of the ventricle is more susceptible to ischemia?
- ----------

Lecture Quiz

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- A- Cerebral
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- D- Cutaneous
- 2- Which part of the ventricle is more susceptible to ischemia?
- ----------Subendocardial layer----------

SUGGESTED TEXTBOOKS

1. Ganong review of medical physiology, 26 th edition, chapter 34. p569-581
2. Essentials of medical physiology , 6th edition, chapter 108, 109 P : 629-638-